Quantum Computing

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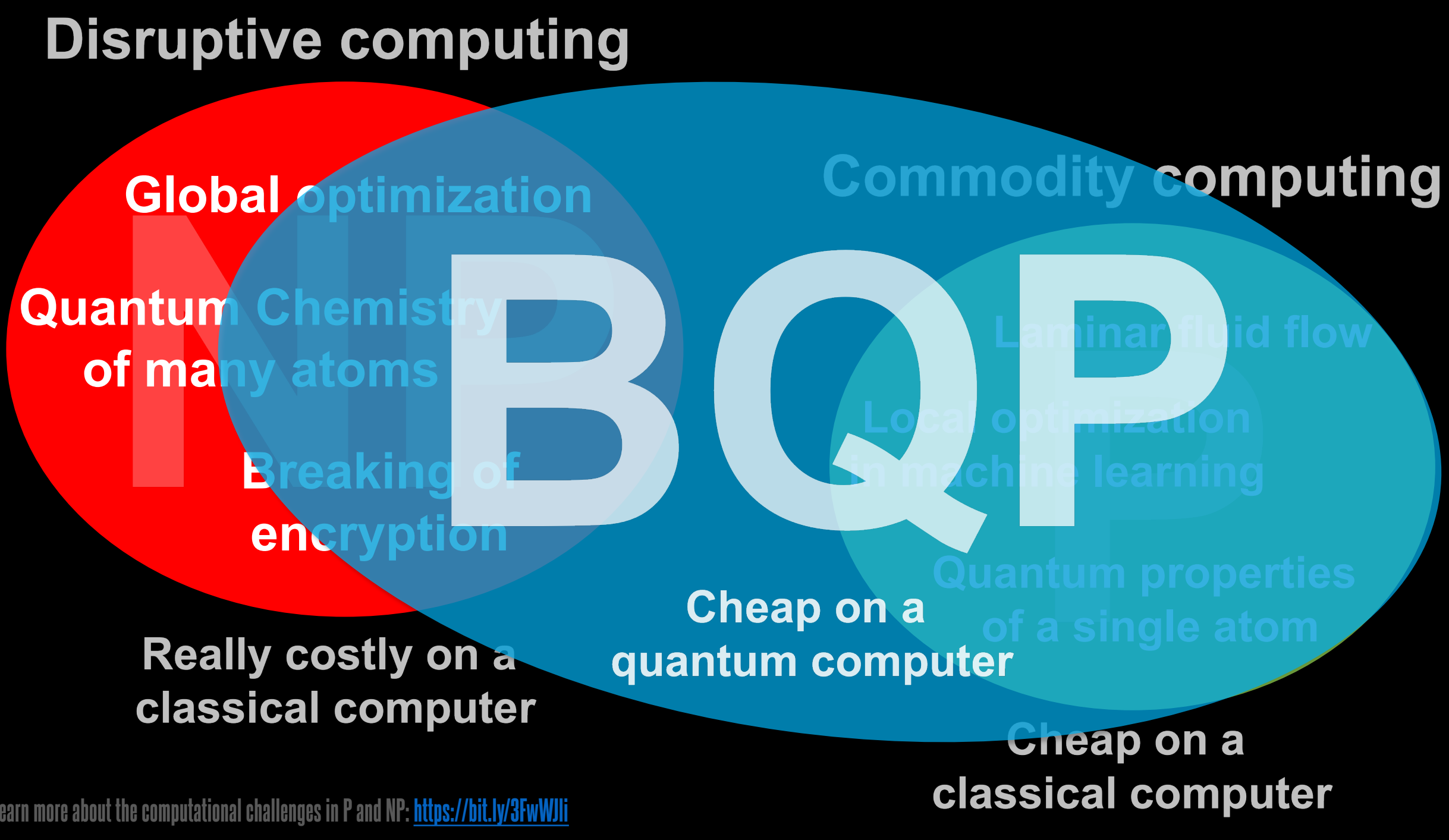
Image from Google Sycamore – Image credit: Erik Lucero/Google, Inc.
For a report on this quantum computer see: https://bit.ly/3MYUpWM

Why do we need a new way to compute?


Disruptive computing
Commodity computing
Global optimization
Quantum Chemistry of many atoms
Breaking of encryption
BQP
Laminar fluid flow
Local optimization in machine learning
Quantum properties of a single atom
Really costly on a classical computer
Cheap on a quantum computer
Cheap on a classical computer
To learn more about the computational challenges in P and NP: https://bit.ly/3FwWJli

The building blocks:

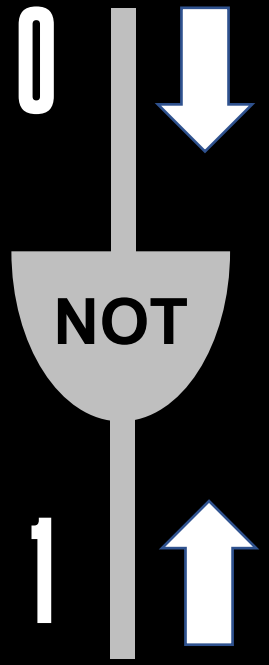
bits vs. qubits

idea craft realization industrial scale

The idea of classical bits

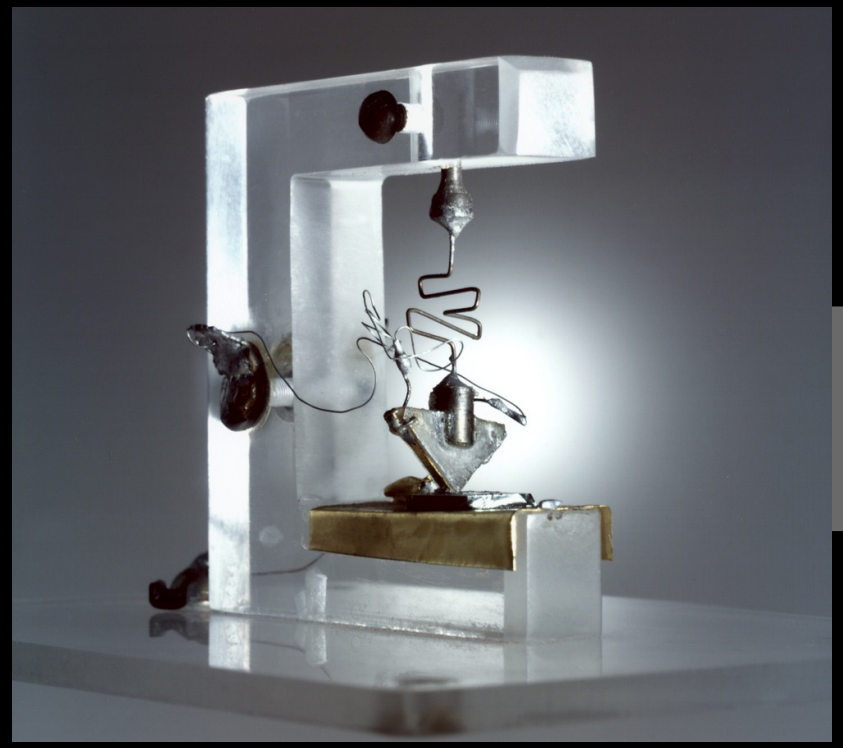
An Arrow
Which is either
up (1) or down (0):

Algorithms built
in the language
of Boolean logic



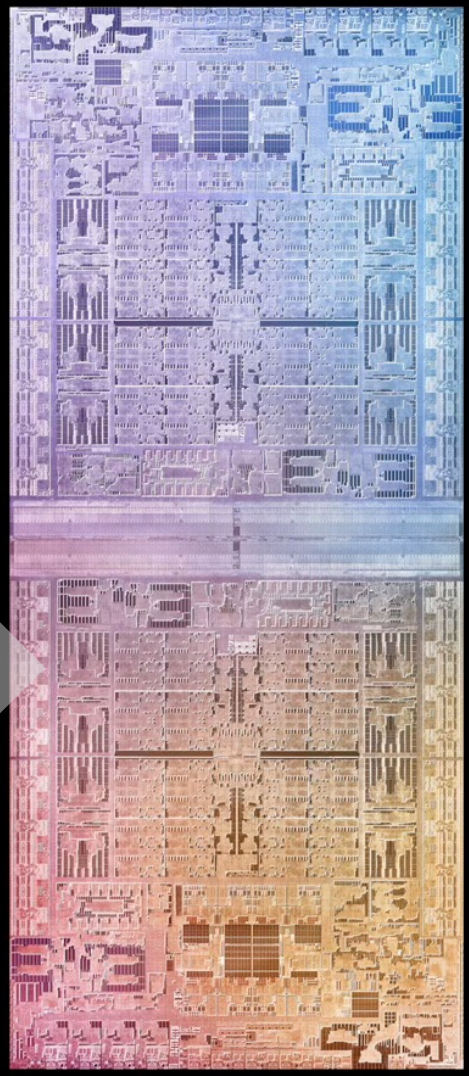
Bits represented by currents (on/off) - operations (Gates) by electronic circuits

To explore the concept of bits: https://youtu.be/gI-qXk7XojA



Replica: UKAEA Harwell, Oxfordshire, England, Science Museum Group Collection

The first transistor made at Bell Labs (1947)



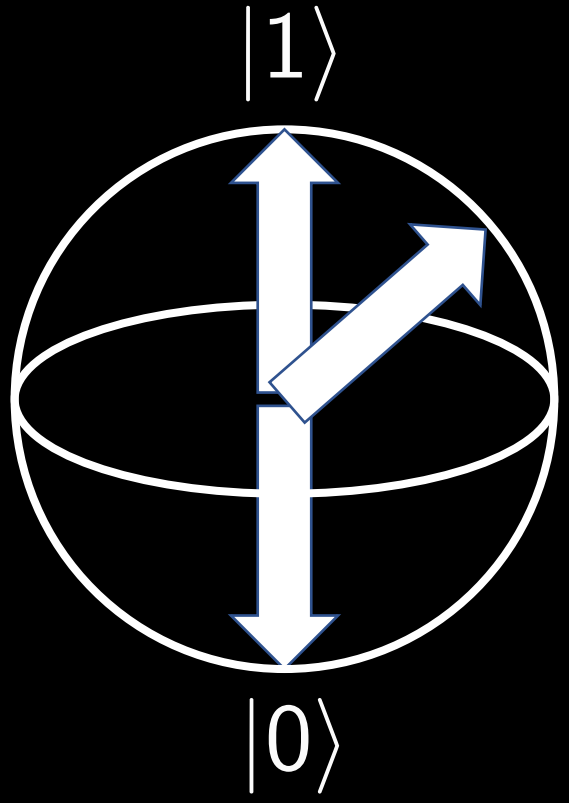
M1 Ultra Apple Corp.

Modern laptop processor with 114 BILLION transistors (2021)

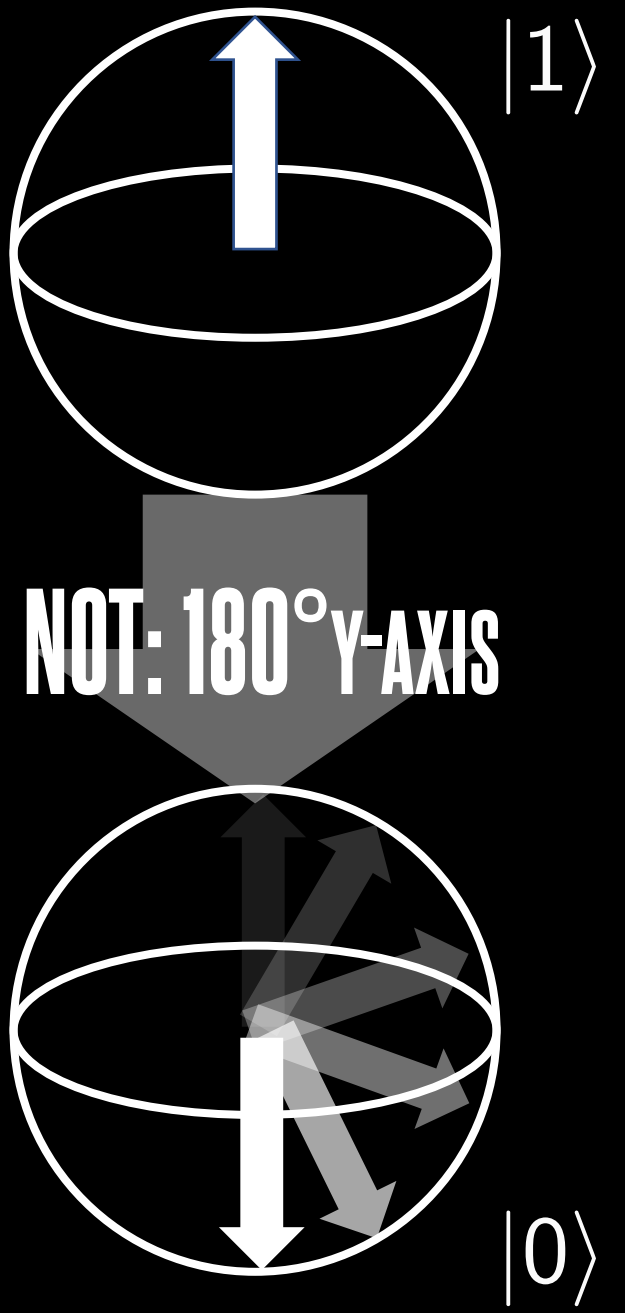
Read more about the history of transistors: https://en.wikipedia.org/wiki/History_of_the_transistor

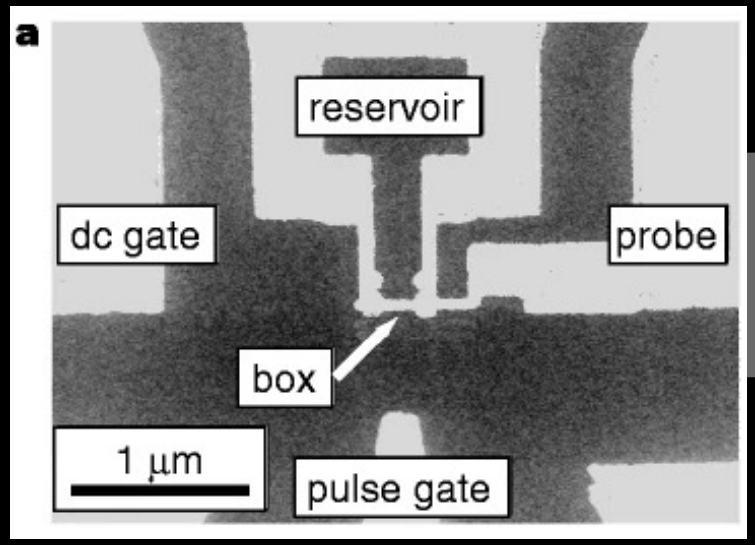
The idea of quantum bits

An arrow fixed at the center of a sphere



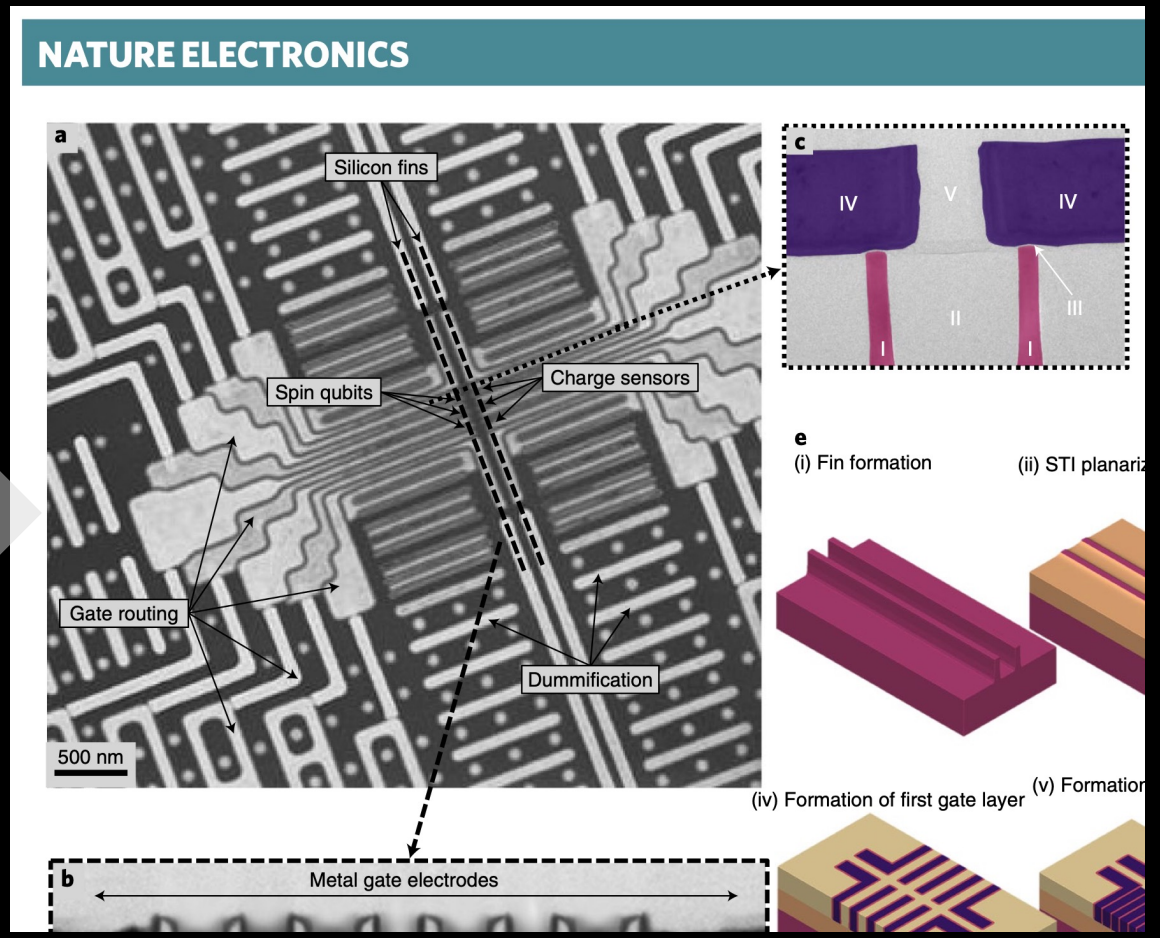
Algorithms built in language of Rotations





Y. Nakamura, Yu. A. Pashkin and J.- S. Tsai, Nature 398, 786-788 (1999)

The first qubit made of silicon NEC/JST (1999)



A. M. J. Zwerver et.al. Nature Electronics volume 5, pages 184–190 (2022)

The first industrially manufactured silicon qubit by INTEL (2022)

State of Qbits changes (Rotations) by using Microwave signals

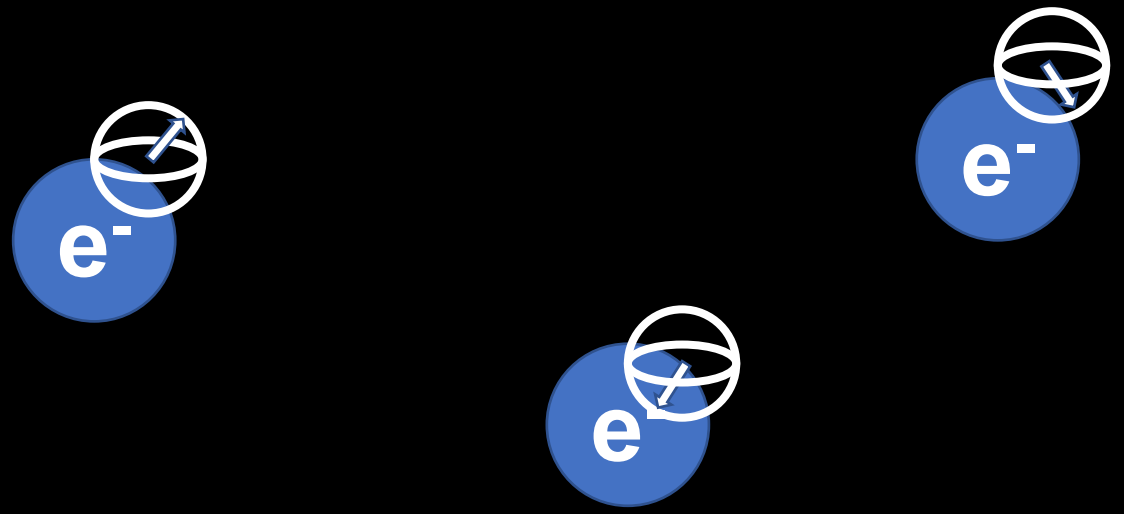
To learn more about semiconductor based qubits: https://bit.ly/3MS9xVy

A quantum birthday

100 year anniversary of the Stern-Gerlach experiment

To learn more about this revolutionary experiment: https://bit.ly/3yl1egZ

1st Revolutionary insight:

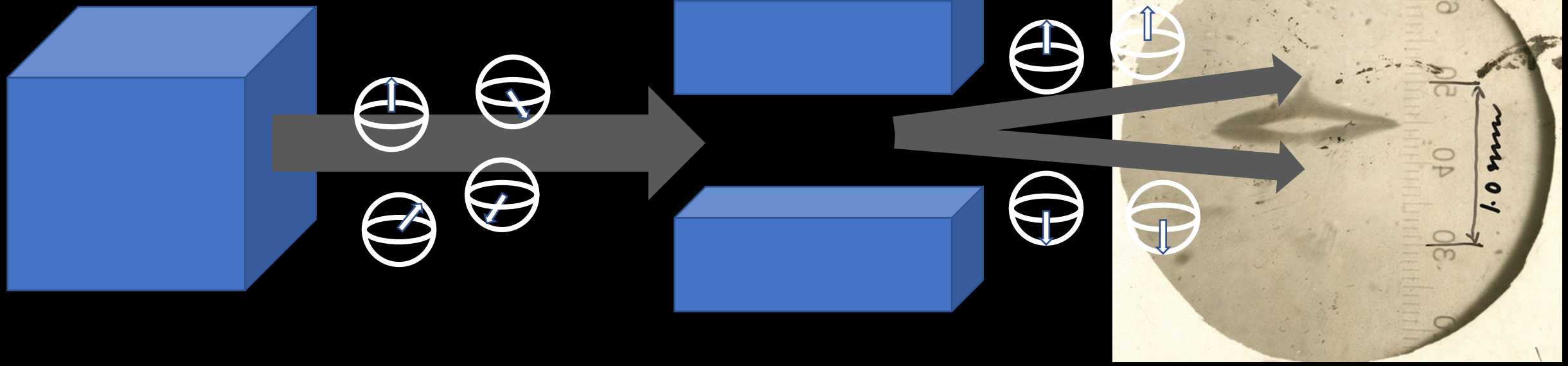


All elementary matter particles are qubits they carry a little arrow called SPIN

2nd Revolutionary insight:

Source of particles

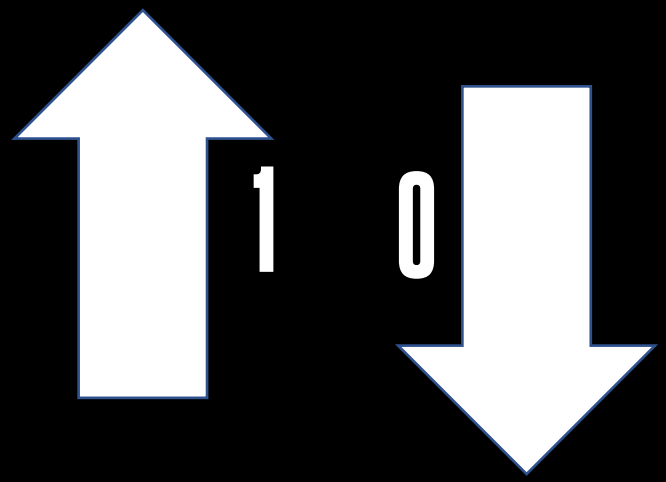
How much do you point UP or DOWN

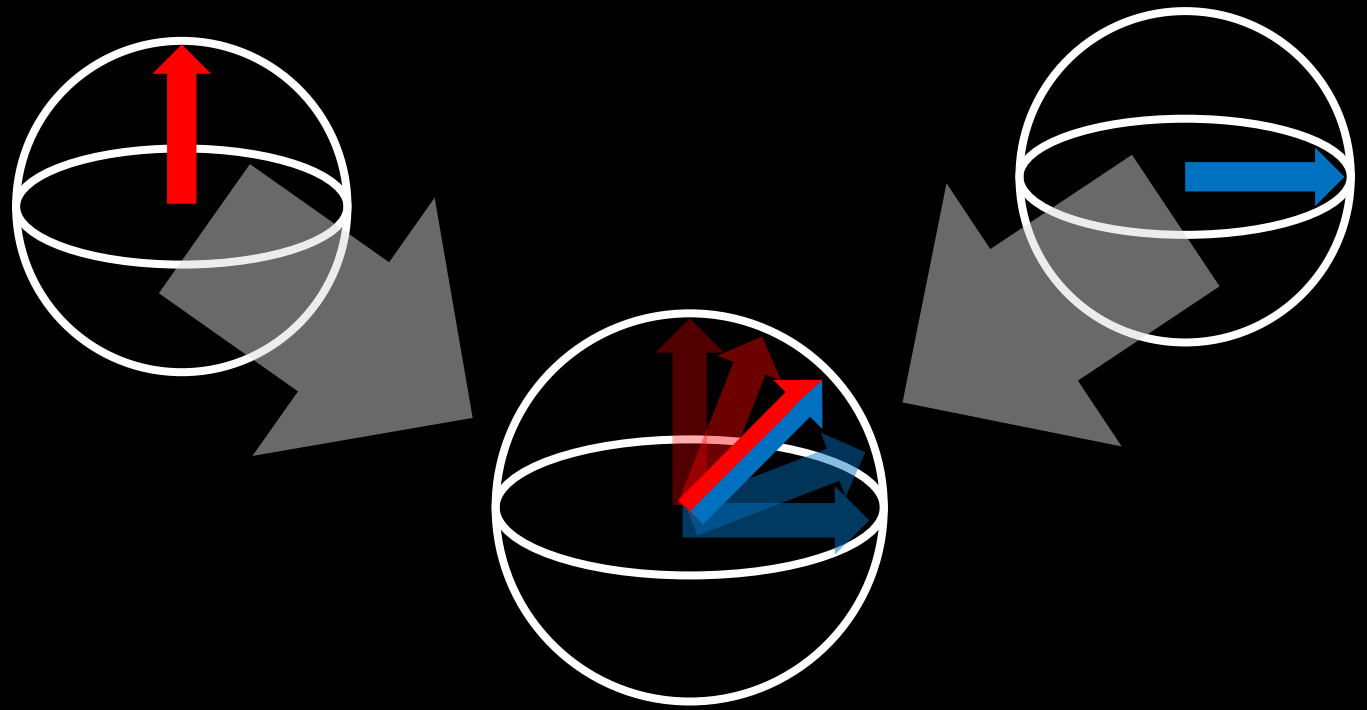


Nature Physics volume 4, page S6 (2008)

Qubits are DISCRETE & flip RANDOMLY into up/down when asked

3rd Revolutionary insight: Quantum Holistics 1+1>2





Two classical bits are unaware of each other

Quantum bits can be made aware of each other due to ENTANGLEMENT

If you want to learn more about entanglemennt check out: https://bit.ly/3wan0q6

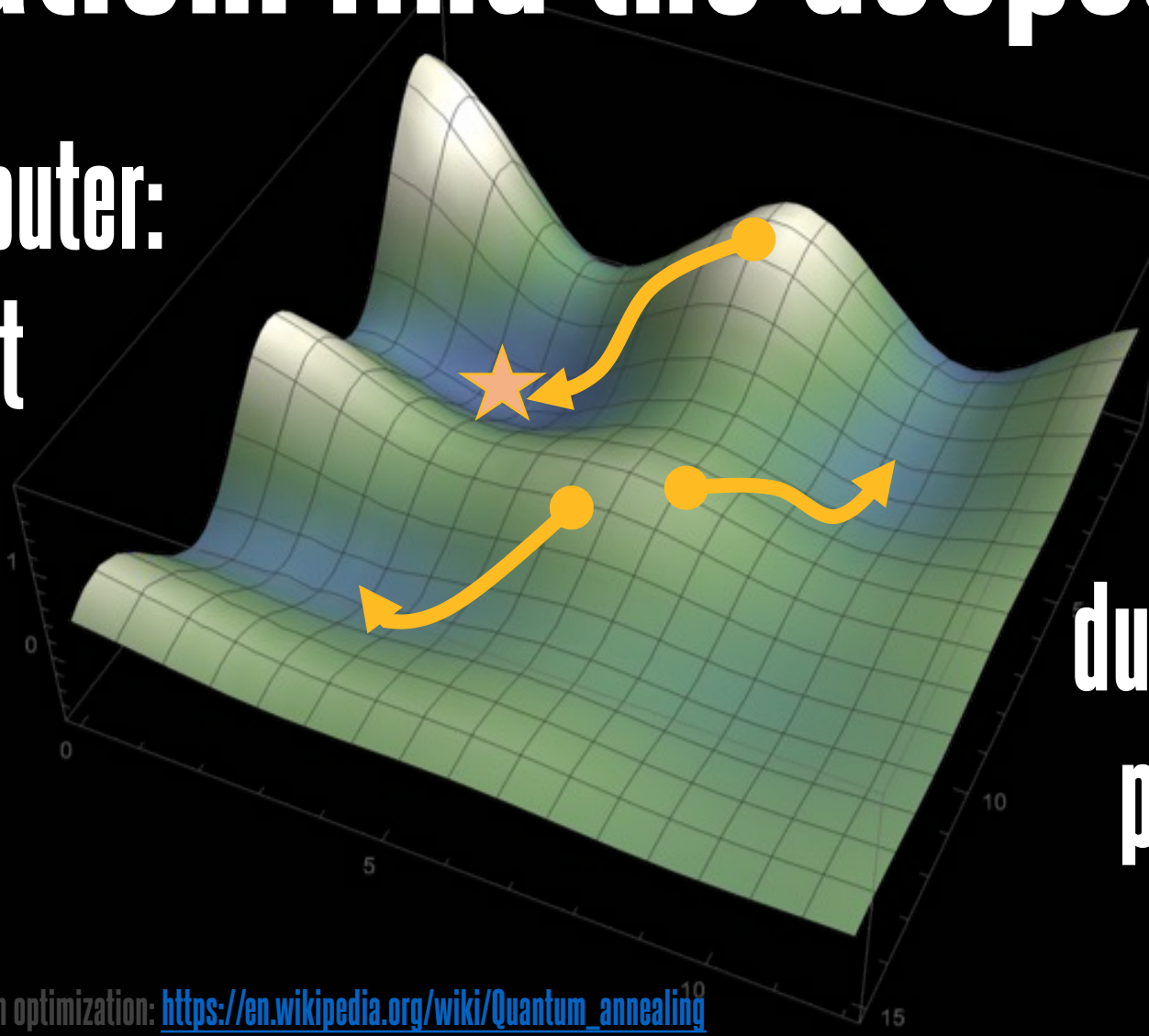
Three tenets of Quantum Machanics

discreteness randomness entanglement

Where is the quantum advantage hiding?

Optimization: find the deepest valley

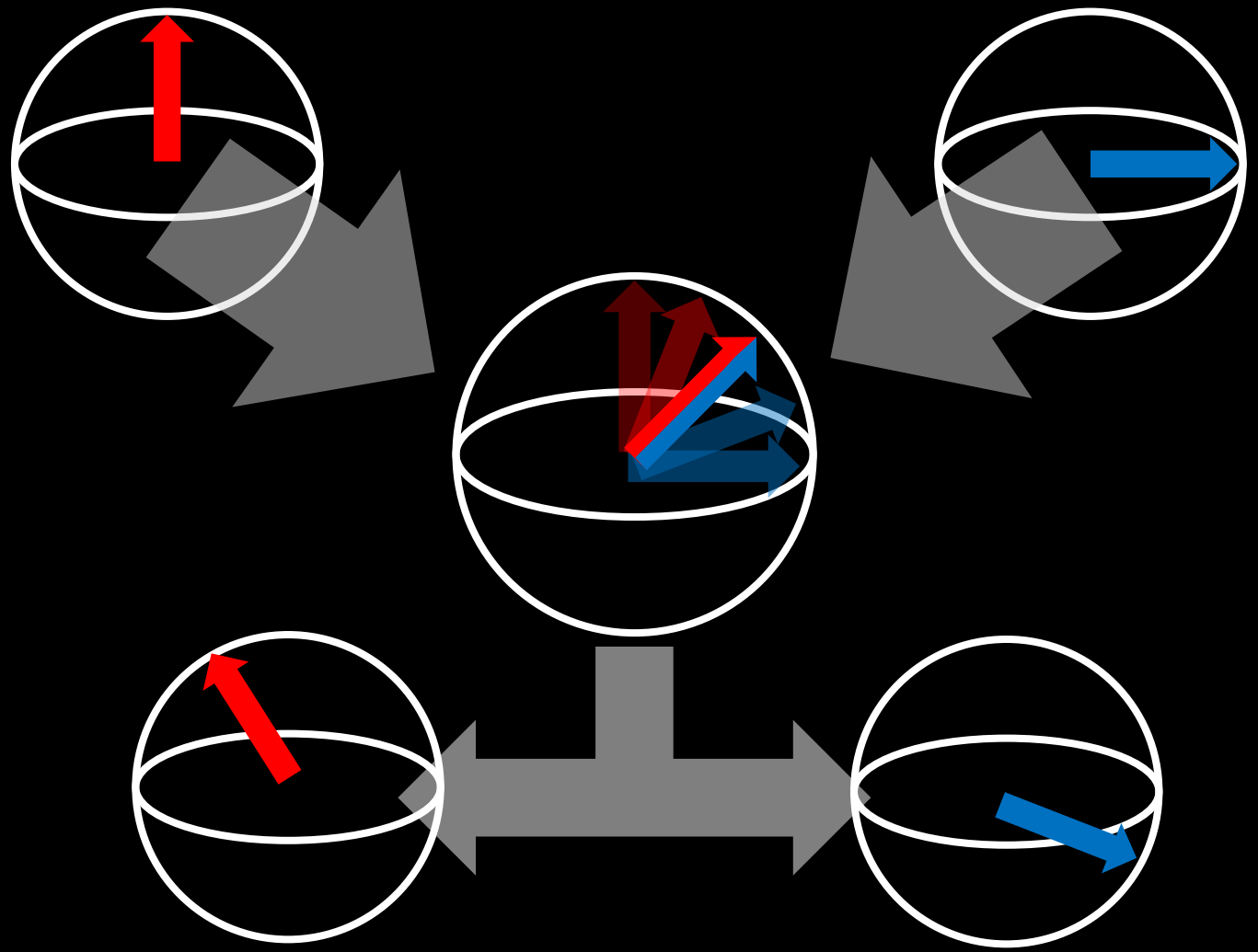
Classical computer:
follow steepest
slope locally



Quantum computer:
due to ENTANGLEMENT
probes many valleys
simultaneously

One strategy to obtain a quantum advantage in optimization: https://en.wikipedia.org/wiki/Quantum_annealing

What prevents quantum advantage?



Loss of entanglement among qubits!

Quantum Computing

Potential for disruptive computing

Based on three Quantum Tenets

Challenge: protecting entanglement